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U. S. Forest Service
Research Paper RM-13

The Beaver Creek Pilot Watershed for Evaluating Multiple-Use Effects of Watershed Treatments

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FOREST SERVICE — U. S. DEPARTMENT OF AGRICULTURE

U. S. Forest Service Research Paper RM-13 June 1965

THE BEAVER CREEK PILOT WATERSHED[1]

FOR EVALUATING

MULTIPLE-USE EFFECTS OF WATERSHED TREATMENTS

by

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[1] A 275,000-acre watershed on the Coconino National Forest in northern Arizona where costs and benefits of intensive multiple use land management are being evaluated as a part of the Arizona Watershed Program.

[2] Central headquarters maintained in cooperation with Colorado State University at Fort Collins; research reported here was conducted at Flagstaff, in cooperation with Arizona State College.

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INTRODUCTION

Water supply problems are serious in many places in the semiarid Southwest. The economic development of many communities may be curtailed by insufficient water for agriculture, industry, and home use. One possibility to increase streamflow is to change the vegetative cover on upstream watersheds.

Before attempting such practices, the effects of these treatments on other watershed values, that is, timber, forage, wildlife, and recreation, must be determined. Also, if such practices are feasible, operational techniques must be developed. These can be done on a small scale by applying treatments on pilot watersheds where detailed records of products and costs are kept. Evaluating the benefits of a large-scale program requires, in addition, the collection of economic data about the particular river basins where such a program is contemplated. The pilot plant then provides a physical basis for evaluation, while the river basin studies provide an economic basis. Both must be harmonized to make the complete evaluation.

The Beaver Creek Pilot watershed (fig. 1) was set up to try watershed management techniques to increase streamflow. This paper describes the study to date. Summaries of the production of different products as a result of past and present management are presented. Product yields are combined in a "product mix" table, which shows the present multiple-use picture for each of three vegetation types. The table provides a benchmark for later comparisons with product mixes resulting from different watershed management treatments. The process for extending physical data from pilot plant to management unit is also discussed.

THE BEAVER CREEK PILOT WATERSHED

The watershed area, 275,000 acres, contains four different vegetation types; each type has a different streamflow potential. Only the three types containing trees are being considered for watershed treatments.

The whole watershed is divided into smaller pilot watersheds (fig. 1). The smaller watersheds will be treated first with a single treatment prescription. In the juniper types, converting the juniper tree overstory to grass, herbs, and shrubs is contemplated. Pine-covered watersheds will receive several conversion and thinning treatments. The larger watersheds--Bar-M Canyon, Woods Canyon, Rattlesnake Canyon, and Dry Beaver Creek--will be used to test combinations of treatments found productive on the smaller watersheds. The objective is to find out how well results can be predicted when several treatments are applied to larger areas. Wet Beaver Creek and Red Tank Draw watersheds will be used to develop operational techniques and determine treatment costs when applied to project-sized areas.

SOME WATERSHED CHARACTERISTICS

The Beaver Creek watershed is generally characteristic of Arizona watersheds. For example, there are about 13 million acres of land in Arizona covered by juniper woodland types and 3 million acres covered by the ponderosa pine type. A pilot plant exhibits some local peculiarities, however, that are not present everywhere. A careful description of these helps to interpret Beaver Creek results.

Some information is now available about precipitation, soils, and watershed cover.

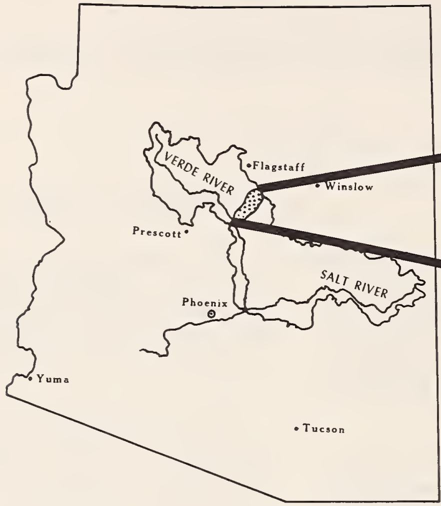
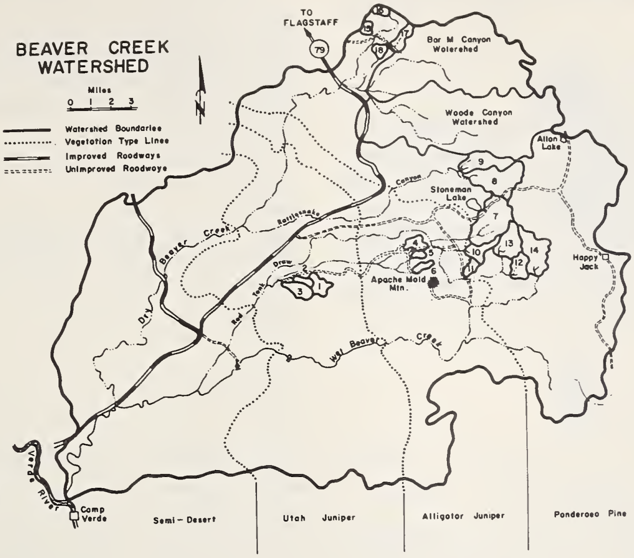


Figure 1.--BEAVER CREEK PILOT WATERSHED:

SEMIDESERT ZONE receives so little rainfall that watershed management is not contemplated at this time.

ALLIGATOR JUNIPER (foreground) is sparse, appears on rolling topography and is interspersed here with turbinella oak.

UTAH JUNIPER (background) occurs on flat benches between deeply cut valleys. It is denser than its sister type.



PONDEROSA PINE occurs on rolling topography. Dense two-storied stands are interspersed with sienagas. Gambel oak is found singly or in copses with the pine.

These seem most important. Other characteristics will be considered as the data become available.

Precipitation

Precipitation is a major limiting factor affecting the amount, timing, and quality of the products produced on the watershed. The Beaver Creek precipitation-measuring network consists of 49 stations. The whole watershed area is covered generally, but gages are concentrated near the small subwatersheds to allow intensive analyses.

Summaries of storm, seasonal, and annual precipitation are made for the various watersheds. These data have been used to help explain streamflow characteristics. They will also be used to refine watershed calibration to speed up the treatment program.

Seasonal and annual range in precipitation amounts to about half the average (table 1). Differences between seasons in any one year are even greater. Seasonal and annual variations are closely associated with differences in product yields, which will be presented later.

Table 1. --Precipitation by vegetation type on Beaver Creek watersheds[1]

Months	Utah juniper		Alligator juniper		Ponderosa pine	
	1958	1959	1958	1959	1958	1959
			Inches			
October	1.49	1.40	2.21	1.00	2.54	0.91
November	3.49	1.61	4.95	1.86	6.43	2.34
December	.66	.03	.92	.05	1.04	.05
January	.38	.57	.43	.61	.58	.79
February	2.65	1.98	3.19	1.76	3.52	2.74
March	3.92	0	4.88	.06	5.81	.06
April	1.69	1.50	1.85	1.64	1.92	1.74
May	.51	.60	.76	.53	.62	.51
June	.10	.43	.34	.70	.87	.99
July	.24	1.86	.76	1.60	.53	1.75
August	2.06	2.99	4.28	3.19	4.27	4.50
September	6.04	.16	4.82	.01	5.74	.22
Total	23.23	13.13	29.39	13.01	33.87	16.60
Average[2]	18.56		20.98		24.85	

[1] In 5 years of record, 1958-62, 1958 is the wettest year and 1959 the driest.
[2] Arithmetic average for the 5-year period, 1958-62.

Soils

Soils have as parent materials basalt, volcanic cinders, sandstone, and limestone.[3] Below 5,000 feet elevation sandstone and limestone predominate. Above 5,000 feet, in the area where watershed treatments are planned, the parent material is mostly basalt and cinders.

Basalt and cinders develop into heavy clay soils. Surface soils (down to about 3 inches in depth) are silty loams or clays. Subsurface soils are nearly all clays or silty clays. Structure is often massive with slow infiltration rates as soils become saturated. Many of the soils, particularly in the pinyon-juniper areas, are montmorillonitic clays. These clays characteristically shrink and swell in response to moisture changes, so that large cracks form during dry periods. These soils also tend to seal quickly as they become wet. Treatments that change plant cover may also change surface soil conditions, and could have a profound effect on the yields of all products.

Detailed soils analyses have been made for the various soils types. The range of soils encountered is relatively narrow (fig. 2). Special soils data were collected at each permanent installation for measuring range and timber products. Relations between soil and these products will be determined.

Watershed Tree Cover

Since tree cover is the characteristic that will be altered in the manipulation of vegetation on watersheds, it needs to be described carefully to: (1) determine treatment feasibility, (2) describe the treatment precisely once it is imposed, and (3) provide a basis for cost analysis. The ponderosa pine on watershed 12 was inventoried in detail to develop efficient methods of inventory.

The point-sampling system used to inventory the timber stands provided data for de-

[3] *U. S. Forest Service. Soil management report for Beaver Creek watershed of the Coconino National Forest, Region 3. 69 pp., illus. July 1960.*

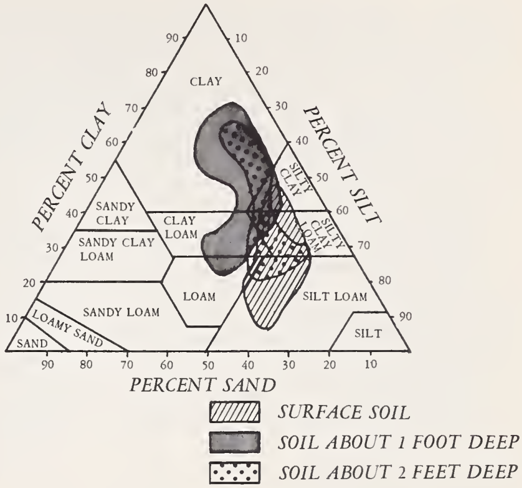


Figure 2.--Soil textures on the Beaver Creek Pilot Watersheds.

scription of stand conditions based on three basal area stocking levels (25, 50, and 75 square feet per acre) so that the portion of a watershed not stocked, stocked, and overstocked with trees of different characteristics at these levels can be determined.

The importance of these data in describing pilot watershed characteristics can be shown by a brief example. Consider a proposition to thin the ponderosa pine to 50 square feet of basal area. Reference to table 2 shows that the treatment would only affect 68 percent of the area. It would not apply to the 16 percent already properly stocked or the 16 percent understocked. The desired stocking would exist on 84 percent of the watershed after treatment. From this and more complex statistics of the same sort, treatment feasibility can be judged. Since the point sample was made to cover the watershed, the treatment can be described precisely by reinventory, and the needed data for cost analysis are available.

WATERSHED PRODUCT HIGHLIGHTS

Streamflow

Potential streamflow changes are the criteria for the selection of watershed treat-

Table 2.--Percentage of area stocked with trees to different basal-area levels, watershed 12

Basal-area level and stand condition	Ponderosa pine: Sawtimber	Ponderosa pine: Poles	Ponderosa pine: Saplings	Ponderosa pine: Reproduction	Ponderosa pine: All size classes	Gambel oak	Alligator juniper	All species
	Percent of area							
25 sq. ft. per acre:								
Properly stocked	38	21	13	13	9	15	14	5
Overstocked[1]	31	43	48	36	87	25	12	94
Not stocked	31	36	39	51	4	60	74	1
50 sq. ft. per acre:								
Properly stocked	28	23	16	16	16	17	10	13
Overstocked[1]	13	25	31	23	68	15	6	77
Not stocked	59	52	53	61	16	68	84	10
75 sq. ft. per acre:								
Properly stocked	20	23	16	16	14	16	8	17
Overstocked[1]	9	16	22	18	60	11	4	67
Not stocked	71	61	62	66	26	73	88	16

[1] Tally of two or more trees with one-tree expectation as a stocking criterion.

ments, and they form one basis for judging the success or failure of treatments. Each of the subwatersheds is stream gaged; a total of 24 gages are used. Eighteen of these are specially constructed flumes on small watersheds; the remaining six gage larger watersheds. Fourteen of the eighteen are designed to measure flow to 320 cubic feet per second (c.f.s.) and four measure flow to 120 c.f.s. Of the six larger watersheds, three are gaged over specially designed weir controls with capacities to 1,000 c.f.s. The other three are measured over mainly natural controls supported by only minimal artificial structures. Data from four of the larger stream gages are taken and summarized by the U. S. Geological Survey.

No record of underground flow is being made. It is believed that the treatments designed to increase streamflow will not significantly affect underground flow since there is little evidence of ground water flow in either the form of springs or in the streamflow hydrographs.

To decide if a treatment affects streamflow, pretreatment streamflow is gaged for several years on a watershed to characterize it in an untreated condition. Classically this is done through a calibration process in which the annual flow of one watershed is compared with that of another to predict streamflow of the watershed to be treated. Once this watershed is treated, streamflow departures from predicted streamflow attest to changes due to treatment. This process usually takes many years, since each year forms but a single observation. In this area of intermittent streamflow, however, it is possible to analyze flow periods instead of yearly totals. This modification is 1.7 times more efficient than yearly totals in the juniper types.

Another step is being taken to further reduce the calibration time to speed up the program. This is an analysis of recession and rising stages from which streamflow characterizations can be described mathematically for a watershed without using control watersheds. Posttreatment changes can then be calculated and summed for seasons or years.

The annual streamflow of the various cover types can be characterized from measurements of small untreated watersheds to show

characteristics of importance to evaluation (table 3). The streamflow from these watersheds varies greatly between watersheds within types for any one year as well as between years. Variability between years follows precipitation patterns closely. Year-to-year variation is about as great as the average streamflow.

Table 3.--Average streamflow in inches[1] from several watersheds on Beaver Creek, by water year (October 1 - September 30) and tree cover type

Cover type and water year	Watersheds	Streamflow per unit area		
		High	Low	Average
	Number	- - - Inches - - -		
Utah juniper:				
1958	3	0.94	0.74	0.82
1959	3	0	0	0
1960	3	.62	.59	.61
1961	3	.28	.16	.21
1962	3	.18	.13	.16
Average		.40	.32	.36
Alligator juniper:				
1958	2	6.05	4.85	5.45
1959	3	.61	.06	.33
1960	3	5.07	3.19	3.91
1961	3	1.19	.44	.85
1962	3	6.00	3.62	5.09
Average		3.78	2.43	3.13
Ponderosa pine:				
1958	2	11.69	11.17	11.43
1959	4	1.04	.17	.42
1960	6	7.49	3.75	5.11
1961	6	2.39	.73	1.50
1962	6	9.05	4.94	6.67
Average		6.33	4.15	5.03

[1] Computed from preliminary area determination for individual watersheds.

Of particular importance is the great variability between watersheds in the same year. Within-year differences represent a greater proportional change in low streamflow years than in high streamflow years. In the pine and alligator juniper watersheds, the bulk of the flow is due to general winter storms, with snow accumulation forming a large part of the effective precipitation. These watersheds maintain consistent ranking in terms of their water yields. Utah juniper watersheds, on the other hand, depend upon local summer storms to a greater extent. The location of these storm centers plays a greater role in annual streamflow so that sometimes one watershed is ranked high and sometimes another. These facts point up the importance of carefully collecting and interpreting hydrologic data to account for these differences to improve predictions, and ultimately to suggest watershed characteristics that may be correlated with high yield to be looked for in other watershed areas.

Suspended Sediment

Suspended sediment samples have been collected from each flume at irregular intervals (table 4). They do not provide data from which total sediment yield can be estimated; rather they were intended to characterize amounts of suspended sediment at different levels of flow.

These data indicate that Utah juniper watersheds contribute far more suspended sediment during periods of streamflow than do the alligator juniper watersheds. Untreated pine watersheds appear to yield least of all. Thinning pine apparently did not produce major sediment increases, while pine-to-grass conversion caused tremendous but short-lived increases.

On a pine watershed during the winter of 1961-62, both bedload and suspended sediment yields were measured for extended periods of flow. About 350 pounds of sediment per square mile were measured for the winter flow; the mineral fraction was composed of 14 percent sand, 47 percent silt, and 39 percent clay (see fig. 2).

Timber Production

Timber production is being estimated on each watershed by a stand projection system.

Table 4.--Suspended sediment in parts per million (p.p.m.) determined from watersheds with different cover conditions, Beaver Creek watershed, 1957-62

Cover type	Samples taken	Maximum suspended sediment measured						Proportion of samples under 500 p.p.m.
		1957	1958	1959	1960	1961	1962	
	Number	- - - - - - - - - - p.p.m. - - - - - - - - - -						Percent
Utah juniper	20	--	6,600	--	3,200	17,400	--	47
Alligator juniper	60	3,000	630	4,500	2,200	120	330	83
Ponderosa pine	280	--	200	20	210	190	110	100
Thinned pine	40	130	480	--	180	320	100	100
Pine cover converted to grass cover	30	--	13,100	560	70	830	230	78

Growth is tabulated in total cubic feet of solid wood per acre per year by tree size and quality classes. Later this is converted to board-foot and cordwood growth.

A preliminary estimate of timber growth on the ponderosa pine portion of the watershed was made from 32 continuous inventory plots (part of the Coconino National Forest control system) on the Beaver Creek watersheds. They were first measured in 1950 and remeasured in 1961.

Data for watershed 12 (table 5), inventoried in the summer of 1962 are fairly typical of the type as a whole.

As different watersheds are treated, effects on the growth of different sizes and qualities of timber will be determined to give a physical background for judging the economic importance of the new timber production.

Herbage Production

Herbage production is estimated at 10 locations within each of the small watersheds (table 6). At each location is a cluster of 10 permanently located 9.6-square-foot plots. Herbage weights are estimated on five of these plots, and five are reserved for clipping to provide a basis for adjusting weight estimates. They provide a measure of the herbage produced by individual species at the particular locations each year. They are inadequate, however, for characterizing production on entire watersheds. Changes due to treatment are determined by periodic remeasurement.

Limited measurement of herbage production on treated areas, adjacent to untreated watersheds, suggests the following increases may result:

Cover type and treatment	Increases in Grass production	Increases in Total herbage
Utah juniper:		
Removed juniper	2 times	2-3 times
Alligator juniper:		
Removed juniper	None	1-1 1/4 times
Ponderosa pine:		
Converted to grass	4-5 times	4-5 times
Thinned to 80 sq. ft. basal area per acre	2-3 times	2-3 times

Increases are based on production estimates made during the first three to four posttreatment years.

Herbage production is low. The range of data suggests large proportional changes due

Table 5.--Annual volume and growth per acre of the timber overstory on watershed 12, measured first in 1950, remeasured in 1961, inventoried in 1962, Beaver Creek watershed

Species and size class	Volume			Growth		
	Cu.ft.	Bd.ft.	Cords	Cu.ft.	Bd.ft.	Cords
PONDEROSA PINE--						
Poles:						
Small (4-6 in. d.b.h.)	233	--	1.04	16.8	--	0.03
Large (8-10 in. d.b.h.)	212	--	2.37	6.1	--	.07
Sawtimber:						
Small (12-16 in. d.b.h.)	181	607	1.91	5.2	16.8	.06
Medium (18-22 in. d.b.h.)	314	1,456	--	.8	3.9	--
Large (24 in. and over d.b.h.)	299	1,673	--	4.6	23.8	--
Total	1,239	3,736	5.32	[1] 33.5	44.5	.16
OAK	198	--	3.72	3.5	--	.04
JUNIPER	109	--	--	.9	--	--
Total	1,546	3,736	9.04	37.9	44.5	.20

[1] Growth of pine determined with standard error of $\pm$ 2.1 cubic feet per acre per year.

to treatment, but the actual changes are small. Analysis by individual species indicates that their production is strongly affected by timing and amount of precipitation.

Steps are being taken to relate soils to forage production. The intent is to map overstory and soils characteristics on the watersheds to determine the proportion of the watershed in different soils-overstory classes. By noting these different soils-overstory classes and weighting them by the area mapped in these classes, an average production figure can be determined for the watershed. Plot-cluster records taken annually will serve to adjust for year-to-year variation.

Table 6.--Herbage produced on plots within untreated watersheds, by cover type Beaver Creek watershed

Cover type	Perennial grasses produced (3 years' record)		Total herbage produced (2 years' record)	
	Range	Average	Range	Average
	- - - Air-dry pounds per acre - - -			
Utah juniper	15- 30	20	200-210	205
Alligator juniper	130-240	190	370-540	450
Ponderosa pine	60-140	100	185-195	190

Wildlife and Recreation

Wildlife and wildlife recreation are being evaluated cooperatively with the Arizona Game and Fish Department. A system of permanent plots on which groups of pellets are counted periodically has been maintained since 1958 to estimate wildlife use of different areas. Deer use is estimated from the widely used average deer defecation rate of 13 groups per animal per day. On this basis, the estimated deer population has averaged seven per square mile for the entire Beaver Creek study area.

Year-to-year populations ranged from 4 to 14 deer per square mile during the period of record, 1958 to 1962. This fluctuation may be due to differences in weather conditions and to a declining herd during this period. Improved sampling techniques are now being used by the Arizona Game and Fish Department to determine the populations of elk and turkey.

Records of wildlife-based recreation are provided by cooperative hunter check stations and traffic counters. Statistics for 1961 and 1962 are as follows:

	1961	1962
Number of hunter vehicles	1,750	2,380
Hunter vehicles as a percent of the total	43.5	54.5
Average number of hunters per vehicle	2.3	1.8
Number of hunters	3,996	4,368
Total days afield	5,994	4,805
Average days afield	1.5	1.1
Deer killed	304	315
Hunter success percent	7.6	7.2
Acres per day afield for area covered (approx.)	25	30

A MULTIPLE USE PRODUCT MIX

To have a beginning point for a multiple use evaluation, a benchmark is needed from which to compare present products with those produced under new practices. It can be established by showing the pretreatment estimates of all the product yields in the form of a product mix table (table 7). A product mix table describes multiple use by spelling out the quantities of products that come from a particular area or class of land. Since all summaries in table 7 are based on less than

Table 7.--Beaver Creek product mix from untreated areas, 1958-62

Cover type	Average yield, by product							
	Water per acre	Forage-grass per acre		Timber per acre per year			Game	Hunter use
		Per year	Total					
	Inches	Pounds, air-dry		Ft.b.m.	Cords	Cu.ft.	Deer/sect.	Hunter days/sect.
Ponderosa pine	5.0	100	190	[1] 44.5	[1] 0.16	[1] 33.5	--	--
Alligator juniper	3.1	190	450	--	--	1-3	--	--
Utah juniper	.4	20	205	--	--	2-4	--	--
Combined types	--	--	--	--	--	--	7	20-25

[1] Watershed 12.

5 years of data, and some from restricted parts of the watershed, this first approximation is crude. The records will be refined and expanded to make future comparisons more precise as the project continues.

Comparison with posttreatment tables will show what is gained and sacrificed in multiple use terms for a redirection of management. Such comparisons form a physical basis for deciding from among alternative practices. For example, it may be decided to increase streamflow by a particular amount, and the pilot plant studies may suggest several ways to do this. A comparison of the product mixes for the several alternatives provides a basis for an appraisal of the advantages and disadvantages in physical product terms.

By comparing before-and-after product mixes, including posttreatment changes, generalizations can be quantified. In a heavy clearing treatment, for example, water, sediment, and forage can be expected to increase, while ultimately timber production will decrease. Game habitat will be affected adversely for some species and favorably for others. Most of the resultant product mixes will not be static, but will change from year to year as the land adjusts to treatment. In the short run, for example, greatly expanded timber harvests will increase economic activity, but finally it must assume a lower level.

FROM PILOT PLANT TO MANAGEMENT UNIT

As soon as posttreatment results become available from the pilot watersheds, they will be generally useful to land managers. Precise quantitative extensions of pilot plant results, however, will rest largely with research in the various technical fields. The pilot plant, then, is a vital link between research results and application. It becomes a proving ground to determine the utility of research results in a project-sized operation. It becomes a developmental laboratory for designing inventory techniques for measuring research variables in the field efficiently enough to be practical for management and precisely enough to lend practical meaning to research results. It points out gaps in knowledge that need to be filled so that recommended management practices can be translated into action.

The above requirements impose several tasks on the pilot watersheds as major responsibilities:

1. To describe the watershed characteristics in detail so that the pilot watershed limits are stated in terms that will harmonize with research work in the various fields. Watershed characteristics described earlier suggest some of the limits set by precipitation, soils, and tree overstory.

2. To develop efficient methods for inventorying independent factors required by research relations so that they can be used for predicting outcomes in larger management situations. Range research, for example, has indicated the relations between timber overstory and forage production. From records of overstory data on range plot clusters, this relation can be determined for Beaver Creek conditions to show the sampling design necessary to get acceptable results.

3. To suggest the needed additional research required to put the pilot tests on the ground and to interpret the results for evaluation. Often treatments that seem simple but are really loosely defined are difficult to put on the ground because of gaps in research knowledge.

   One example of this is control burning a ponderosa pine watershed. On the face of it this sounds simple. But pilot plant objectives and administrative prudence require asking the why, when, what, how, where questions, and it becomes apparent that really too little is known to make effective use of a watershed by just intentionally burning it. Thus a fire research project has been located near the pilot watersheds to provide background information about the use of fire on a pilot test basis. A decision to burn can then be defended on technical grounds, and adequate descriptive data can be collected from the pilot watershed about the fire and analyzed for inter-

pretation and later extrapolation to other areas.

Another example involves interpretation of herbage production records so they will have meaning in an economic evaluation. Herbage becomes forage, and an economic reality, when it is consumed by livestock and game. Since watershed treatments are likely to increase forage quantities and change forage quality, their effects on meat production and animal gains become an important economic question. This question led to a separate study designed to determine the influence of tree overstory on forage and beef production, and the relation of the quality and quantity of forage eaten to animal weight gains. A similar study is anticipated by the Arizona Game and Fish Department to characterize treatments in terms of deer potential. These studies will help in the interpretation of watershed treatment effects on the range resource, and will point out the measurements that require special attention in inventories so efficient methods suitable for large-scale management can be developed.

The implication of the foregoing is that, as a result of the pilot plant operation, (1) questions are asked of research, (2) methods are developed for predicting watershed treatment outcomes, so that (3) before-and-after product mixes can be determined for other areas generally similar to the pilot plant. This will enable land managers to determine the product mix and economic data about their problem areas to help them decide the best treatment.

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1965. The Beaver Creek pilot watershed for evaluating multiple use effects of watershed treatments. U. S. Forest Serv. Res. Paper RM-13, 12 pp., illus. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Pilot watershed treatments to increase streamflow are being evaluated in central Arizona to determine multiple use effects on the major forest resources. Methods are being developed for predicting watershed treatment outcomes, so that before-and-after product mixes can be estimated for similar areas.

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